§28. Nonlinear Incompressible Poloidal Viscosity in L=2 Heliotron and Quasi-Symmetric Stellarators

Yokoyama, M., Nakajima, N., Okamoto, M.

The nonlinear incompressible poloidal viscosity in the plasma periphery has been evaluated for the $L = 2$ LHD heliotron and quasi-axisymmetric (QS) stellarators, which indicates the possibility of occurenece of the L-H transition. When the poloidal viscosity as a function of the poloidal Mach number M_p has a local maximum, poloidal Mach number has a possibility to bifurcate from lower M_p (L mode) to higher M_p (H mode). The appearance of local maxima depends on the relative amplitudes between toroidicity and helicities in the magnetic field.

In the LHD standard configuration, Fourier spectra of the magnetic field strength $|B|$ in the Hamada coordinates are significantly different from those in the Boozer coordinates. The dominant helicity in the Boozer coordinates with the same poloidal and toroidal mode numbers as the $L = 2$ helical coil windings is converted to its satellites due to the mode coupling in the coordinate transformation. These helicities cause their local maxima around $M_p \gtrsim |m - nq|/m$, where m (n) detotes the poloidal (toroidal) mode number and q the safety factor. These helicity induced local maxima (HM) shade the toroidicity induced local maxima (TM) occuring around $M_p \gtrsim 1$, which would make difficult to realize the bifurcation of M_p in the appropriate Mach number.

Effects of magnetic configuration control on the poloidal viscosity are also investigated to approach the favorable properties from the viewpoints of poloidal rotation in the LHD $L = 2$ heliotron. The less inward magnetic axis shift at zero beta is attractive for the possibility of the bifurcation of the poloidal flow velocity. The quadrupole induced horizontally elongation of the magnetic surface cross sections effectively decreases $\Pi_{p,n}$ to maintain the poloidal flow velocity. However; these magnetic configurations have degraded properties on the particle orbit confinement compared to the LHD standard configuration. Therefore, compatibility between these properties should be explored based on the investigations of the relationships between magnetic configuration control and magnetic field spectra. The magnetic field spectra in the Hamada coordinates often deviate from those in the Boozer coordinates, and are difficult to consider intuitively. Therefore, it would be helpful to derivate the expression for the poloidal viscosity in the Boozer coordinates to grasp the effects of magnetic configuration control on the poloidal rotation properties.

QS configurations are examined because the maintaining of the plasma rotation is considered as the one of the attractions for QS concepts. The QS properties are typically discussed in the Boozer coordinates from the particle orbit point of views. The QS properties in the Boozer coordinates are well maintained even in the Hamada coordinates. This is due to the well suppressed non-symmetric magnetic field spectra in the Boozer coordinates, which causes very little mode coupling in the coordinate transformation to the Hamada coordinates. Therefore, TM (HM) appears sufficiently clearly in an example QAS (QHS) configuration, which implies that there is a possibility of the bifurcation of the poloidal flow velocity in the appropriate Mach number.

These clear local maxima appearing around different M_p ($M_p \sim 2\,(4)$ for an example QAS (QHS) configuration) and the variation of the dependence of poloidal viscosity on M_p possible by the magnetic configuration control in LHD $L = 2$ heliotron would provide the good opportunity to test this bifurcation model in a wide range.